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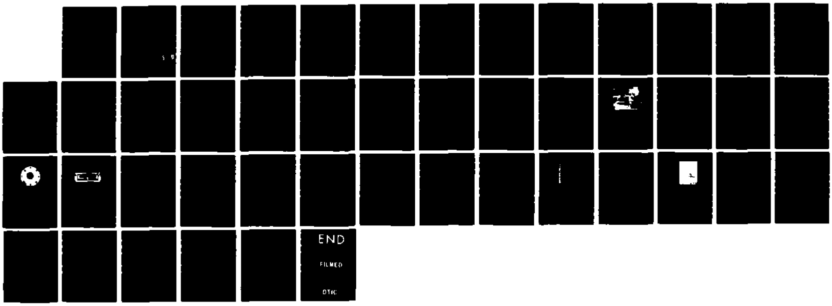

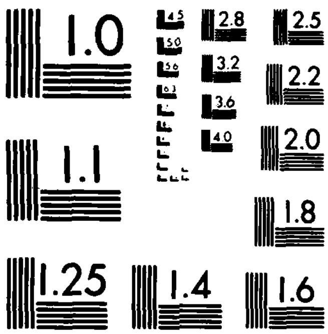
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University of Illinois at Urbana-Champaign
Urbana, IL 61801

Technical Report UILU ENG 84-4001

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RESEARCH TEST FACILITY
FOR EVAPORATION AND COMBUSTION OF
ALTERNATIVE JET FUELS AT HIGH
AIR TEMPERATURES

Annual Technical Report
AFOSR Contract No. F49620-83-K-0027

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Improved gas turbine combustion performance will require the effective utilization of alternative fuels and advanced combustor concepts. Therefore, further understanding of spray combustion processes including fuel evaporation and flame propagation is required. In pursuit of this goal research is underway which features a high pressure and temperature non-viatiated air system to provide air at simulated gas turbine inlet conditions. A special fuel injection system was designed to produce monodisperse sprays for the purpose of

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This report represents a summary of the engineering activities during the first year of a two year contract focused on the construction of a combustion test facility in which the evaporation and burning rates of jet fuels can be measured as a function of inlet conditions and fuel properties. A large heat exchanger facility which supports this research and can deliver continuously non-vitiated air at flowrates up to 1kg/sec and 700 kPa at temperatures from 300 to 900 K was refurbished for this project. A combustion tunnel was designed and built which features an evaporator/combustor test section that provides good optical access for Laser Doppler Velocimetry, forward scattering drop sizing and high speed photomicrography. Also included in the report are the design of the fuel injection system and test results of the injector showing monodisperse sprays with drop diameters of ~ 70 μm.

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RESEARCH TEST FACILITY FOR EVAPORATION AND COMBUSTION OF ALTERNATIVE JET FUELS AT HIGH AIR TEMPERATURES

prepared by

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ABSTRACT

Improved gas turbine combustion performance will require the effective utilization of alternative fuels and advanced combustor concepts. Therefore, further understanding of spray combustion processes including fuel evaporation and flame propagation is required. In pursuit of this goal research is underway which features a high pressure and temperature non-vitiated air system to provide air at simulated gas turbine inlet conditions. A special fuel injection system was designed to produce monodisperse sprays for the purpose of evaporation and eventual combustion experiments in our newly developed test facility.

This report represents a summary of the engineering activities during the first year of a two year contract focused on the construction of a combustion test facility in which the evaporation and burning rates of jet fuels can be measured as a function of inlet conditions and fuel properties. A large heat exchanger facility which supports this research can deliver continuously non-vitiated air at flowrates up to 1 kg/sec and 600 kPa at temperatures from 300 to 900K. Details of the evaporation/combustion test section are described. Also included are the design of the fuel injection system and test results of the injector showing monodisperse sprays with drop diameters of ~70 μm.

I. INTRODUCTION

A. Overview

Alternative fuels derived from coal and oil shale sources have properties characteristically different from petroleum based fuels that can affect their use and performance as fuels in modern day turbo-jet engines. The use of such fuels by the Air Force or by civil aviation requires that appropriate understanding of the fundamental combustion processes be available.

Five important areas concerning the design of gas turbine combustors with regard to the use of alternative fuels are illustrated in Fig. 1. Alternative fuels often have increased viscosities and volatilities which can degrade engine performance through poor atomization and reduced evaporation rates. Experimental measurements will be made to quantify these effects in order to suggest appropriate combustor design changes. These design changes can be more efficiently implemented with the use of computer models to predict the consequences of new fuels and combustor designs. Different models have been suggested in the literature to predict two-phase, turbulent flow and therefore various computer models will be considered in this program to compare with experimental results to identify deficiencies in the models. The trend toward higher pressure ratio engines indicates the need for spray combustion studies at the high pressures and temperatures that can be obtained in our facility. Advanced combustor concepts include variable mixing schemes and prevaporized/premixed combustors. Both techniques involve design tradeoffs and detailed studies are required to optimize, for example, the amount of fuel to be vaporized or the amount of air that can be

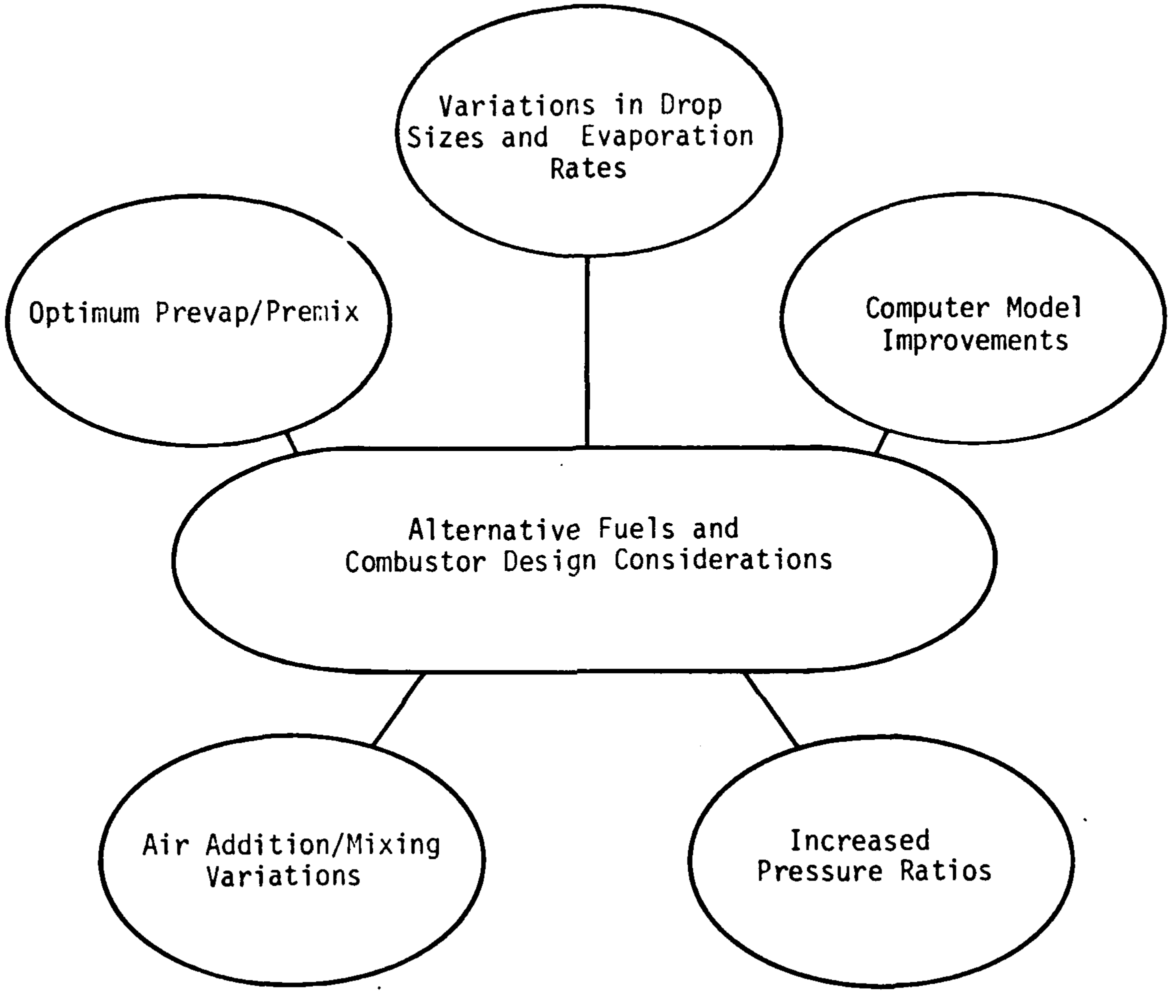

Figure 1. Specific Areas Addressed in the Research Program

added to the primary zone without significantly reducing ignition and flame stability limits. Consequently this program will include both variations in the percent of fuel vaporized and mixing.

B. Current Combustor Development Problems

Improved engine performance to provide acceptability of engines to a wider range of fuels, longer range aircraft, increased lifetime, and minimum initial and operating costs will, to no small degree, require better understanding of combustion processes and the advancement of combustor designs. For example, the introduction of alternative fuels which are often heavier (increased viscosity and decreased volatility)[1] than current specification fuels can result in decreased ignition and altitude relight capabilities[2, 3] and a decrease in combustion efficiency particularly at low power conditions.[4,5] These changes result in a large part from the larger drops and drop lifetimes associated with the sprays of alternative fuels. Therefore, these problems require an understanding of the spray combustion process in gas turbine type flames to provide corrective changes to the combustor, such as improved injector performance, to reduce the detrimental effects of alternative fuels.

Advanced combustor concepts include prevaporized/premixed, two-stage and variable geometry combustors. The prevaporized and premixed concepts arise from a desire to reduce NO_x emissions and soot production by eliminating stoichiometric regions in the combustor which are conducive to the formation of thermal NO_x and soot[6,7]. Unfortunately, this can also lead to reduced stability limits which may lead to ignition and/or lean blowoff problems. Data on evaporation rates of sprays (rather than single drops) under typical

pressures and temperatures in gas turbines would enhance vaporizer development; flame propagation rates in sprays with known and well controlled drop size and fuel liquid to vapor ratios would help the designer optimize the stability limits and the emissions from the burner. For example, one two-stage combustor[8] employs a carburetor tube in the main burner to partially prevaporize and premix the fuel. Here information is needed on evaporation rates in order to improve the design of the carburetor tube and on flame propagation rates to determine, for example, the amount of fuel to be evaporated to optimize the injection system.

Variable combustor geometry provides changes in the air addition to the combustor to obtain variations in equivalence ratios and mixing in different regions of the combustor. For example, for good altitude relight capabilities, the primary zone equivalence ratio increase (as compared to the equivalence ratio at cruise conditions) desired can be obtained by reducing the air flow to the front end of the combustor. This can also reduce the velocity in the ignition region which is beneficial to ignition as well. To achieve proper air flow (and fuel flow) staging the regions of intense energy release as determined by the fuel spray trajectories, evaporation rates and by the mixing in the combustor must be understood.

C. <u>Review of Previous Work</u>

Although many studies have delt with the combustion of single drops we are more interested in the burning of sprays where the combustion process can be quite different from single drop burning, giving results which often differ from those obtained with single drop work. Consequently only combustion experiments performed on sprays

are considered here.

The variables of importance in homogeneous combustion systems, such as temperature, pressure, equivalence ratio, etc., are also of interest in spray combustion. However, additional parameters must be considered, including drop sizes, drop number density, mixing, and equivalence ratios based on fuel in the liquid and/or vapor phase. To determine the individual effect and importance of these parameters on combustion performance, detailed and well controlled experiments are required.

An important parameter used to characterize a flammable mixture is the speed at which a flame will propagate through the mixture. Flame speeds are well documented for many homogeneous fuel and air mixtures, but flame speeds in fuel spray and air mixtures have been determined for only a limited range of variables.

The study of flame speed in sprays is complicated by the appearance of at least two mechanisms for propagation.[9-13] For small drops (diameters less than approximately 10 μm) the drops are evaporated by heat from the approaching flame front. Then the fuel and air mix and the flame passes through the mixture in a manner very similar to flame propagation in a homogeneous mixture. For large drops, evaporation is not complete as the flame reaches the drops resulting in diffusional mode burning, either separately or in groups, depending on the number density of the drops. This second type of behavior results in flame propagation speeds which are often quite different from homogeneous mixture flame speeds.

For fuel lean mixtures, the diffusional burning can promote flame propagation since the drops act as high temperature heat sources which in turn accelerates the local burning velocity by the ignition of

neighboring drops. Other mechanisms for the enhanced flame speeds may include mixing enhancement due to high thermal and concentration gradients and wrinkling of the flame front which increases its surface area and velocity.[10] Thus the presence of drops can actually enhance flame speed and extend the lean limit.[9-12,14]

Alternately, large drops (diameters in excess of 40 μm) which evaporate at a much slower rate can impede flame propagation.[14-16] Here the flame is slowed due to the time required for fuel to evaporate from the drops before combustion can begin. These effects of drop size on flame propagation can also be found for the fraction of fuel in the liquid phase. That is, an increase in the percentage of fuel in the liquid phase may either decrease or increase flame propagation.

The influence of drop size and amount of fuel in the vapor phase on flame propagation indicates that the evaporation rate of the fuel is important in the overall combustion processes. This importance is very evident in gas turbines by the influence of drop size or evaporation rate on typical performance parameters such as ignition, lean limit stability and combustion efficiency[2].

For example, in Figs. 2 and 3, the effects of fuel type on ignition and lean limits are given for the TF41, a can-annular gas turbine combustor manufactured by Detroit Diesel Allison. Properties for the three fuels are listed in Table 1; the JP-4 and JP-8 are "standard" fuels while ARF represents the AGARD research fuel. Generally speaking, JP-4 is the "lightest" fuel as indicated by the lower boiling points and viscosity. ARF is a representative of possible future alternative fuels with higher boiling points, higher viscosity and lower hydrogen content. In both Figs. 2 and 3 the

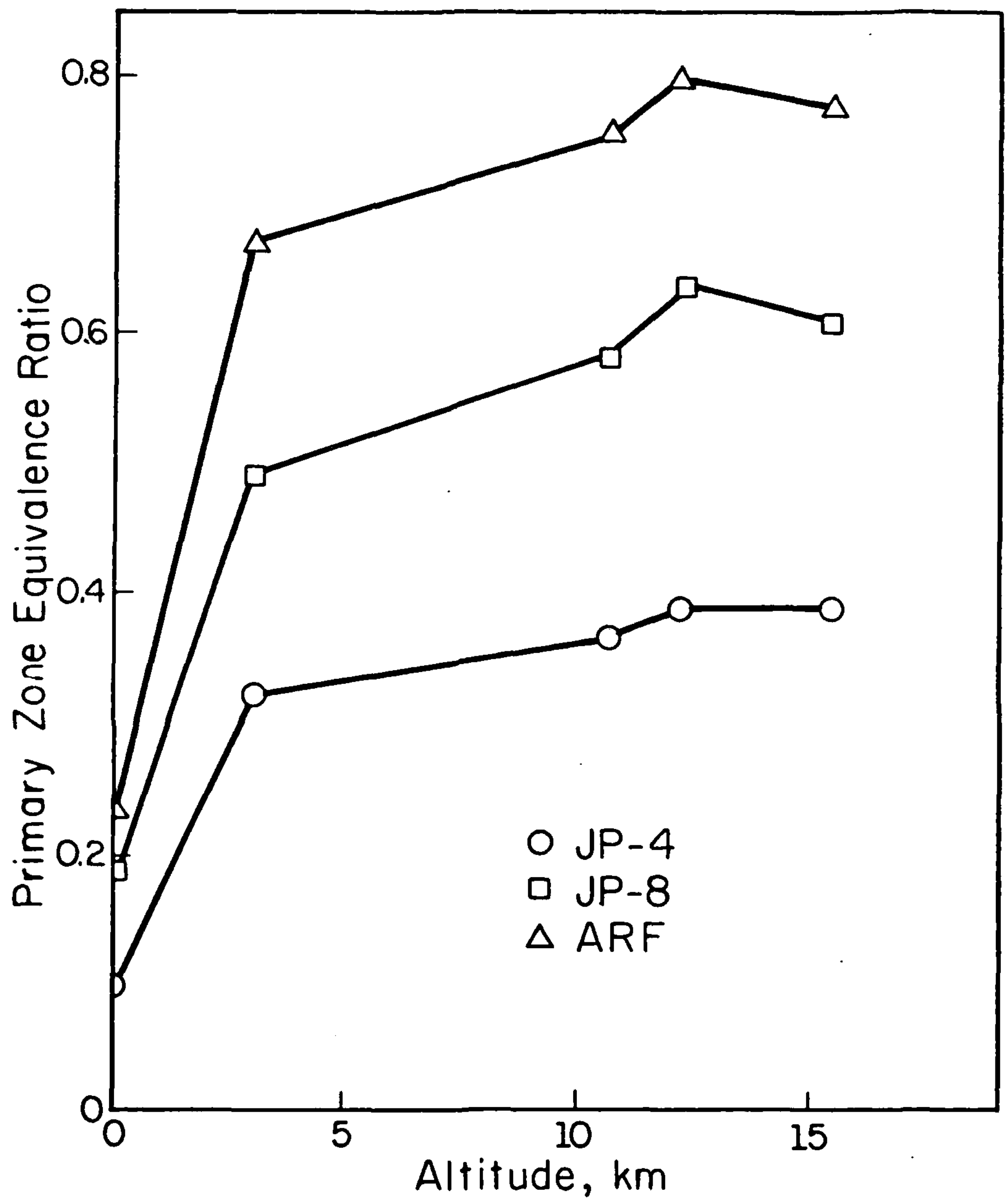

Figure 2. Predictions of primary zone equivalence ratio required for ignition as a function of fuel type for the TF41.[2]

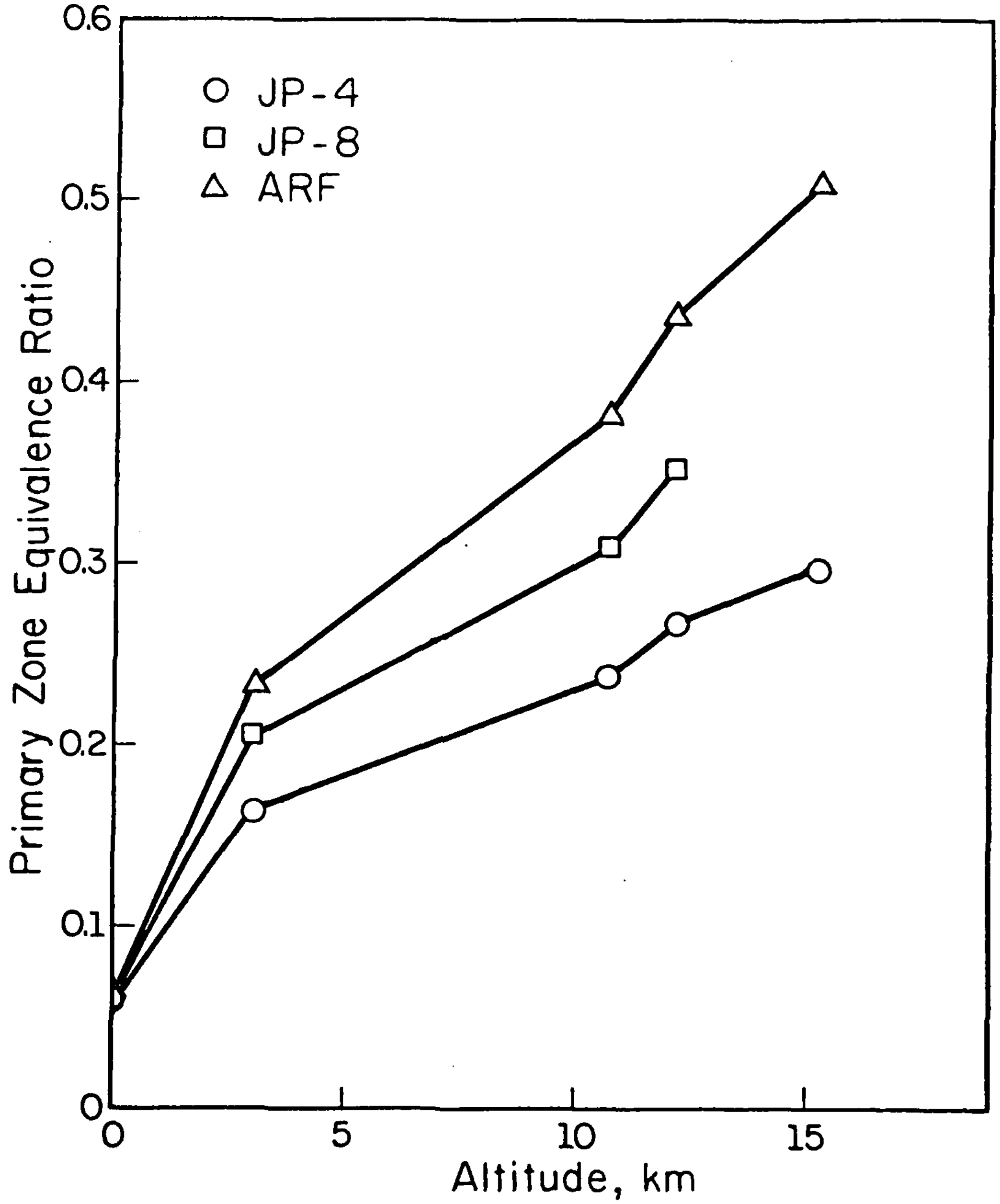

Figure 3. Predicted lean limit primary zone equivalence ratios as a function of fuel type for the TF41.[2]

Table 1 Fuel Properties

Property	JP-4	JP-8	ARF
Density at 21° C, g/cm^3	0.760	0.807	0.800
Viscosity at 25°C, cs	0.98	1.94	3.75
Surface Tension at 21°C, dynes/cm	23.7	26.9	26.3
Hydrogen weight %	14.4	13.9	13.2
Lower Heating Value, MJ/kg	43.5	43.1	43
10% boiling point, K	360	451	478
50% boiling point, K	438	499	525

heavier fuels require a higher primary zone equivalence ratio for operation. This is due to the decreased evaporation rates from the lower volatility and increased drop sizes that accompany the heavier fuels. Such severe changes in primary zone equivalence ratio can adversely affect fuel scheduling and combustor performance parameters such as soot and NO_x production.

We have thus established that drop size and/or evaporation rate can be very important in fuel spray combustion and gas turbine performance. The fundamental studies above indicate that the influence of drop size and/or the amount of fuel in the liquid phase on flame propagation (enhancement or retardation) depends on the conditions of the mixtures. Unfortunately, the data in these studies were obtained over a limited range of temperatures and pressures, for the most part atmospheric pressure and temperature, and some sub-atmospheric pressures. Therefore, the calculations of flame propagation rates and lower limits of propagation at the high pressures and temperatures typical of gas turbine applications are estimates at best. Furthermore, with one exception, (Ref. 16) the data are available only for "neat" fuels or kerosene. Data on alternative fuel effects on propagation at realistic conditions are needed because these new fuels can have evaporation times larger by a factor of four than today's fuels[1] and as we have stated, evaporation can play a stong role in flame propagation and gas turbine performance.

Consequently, a research effort is underway in which we can study evaporation and flame propagation in fuel spray mixtures. The apparatus described in Section II will feature a high pressure and temperature air system to provide data under simulated gas turbine

conditions. Also described is a special injector, capable of handling alternative fuels as well as standard fuels, which allows the generation of monodisperse sprays with variable drop size, droplet number density and velocity.

II. EXPERIMENTAL FACILITIES

A. Facility Overview

An early stage of the work carried out this past year was the construction of the laboratory rooms that house the experiment. As can be seen in Fig. 4 the laboratory area is divided into a control room and a test cell. The experiment is remotely controlled from the control room and the combustion flow tunnel is situated in the test cell. Personnel safety was a prime consideration in the design. Double thickness walls with sandwiched steel mesh protect against possible projectile penetration; bullet-proof glass windows allow for safe observation of the test section.

The general operation of the system is described below. Air flow is regulated via upstream and downstream pneumatically controlled valves which allow independent variation of mass flowrate and pressure. The air system is fed by two compressors which can supply air flowrates of 1 kg/sec at 600 kPa continuously. A tank farm provides 115 m^3 of storage at pressures up to 800 kPa for air flowrates in excess of 1 kg/sec for limited duration runs. The compressed air flows through a Trane Thermal CDF-1050 two pass heat exchanger which provides heated non-vitiated air at temperatures up to 900 K. The mass flowrate of air is measured with a Meriam Accutube (area averaging pitot-static probe) as the air enters the heat exchanger.

The hot air enters the test section through a tubular flow straightener followed by a thermocouple rake which is used to determine the inlet temperature profile. The flow continues through a second straightener that also supports the fuel injector body and

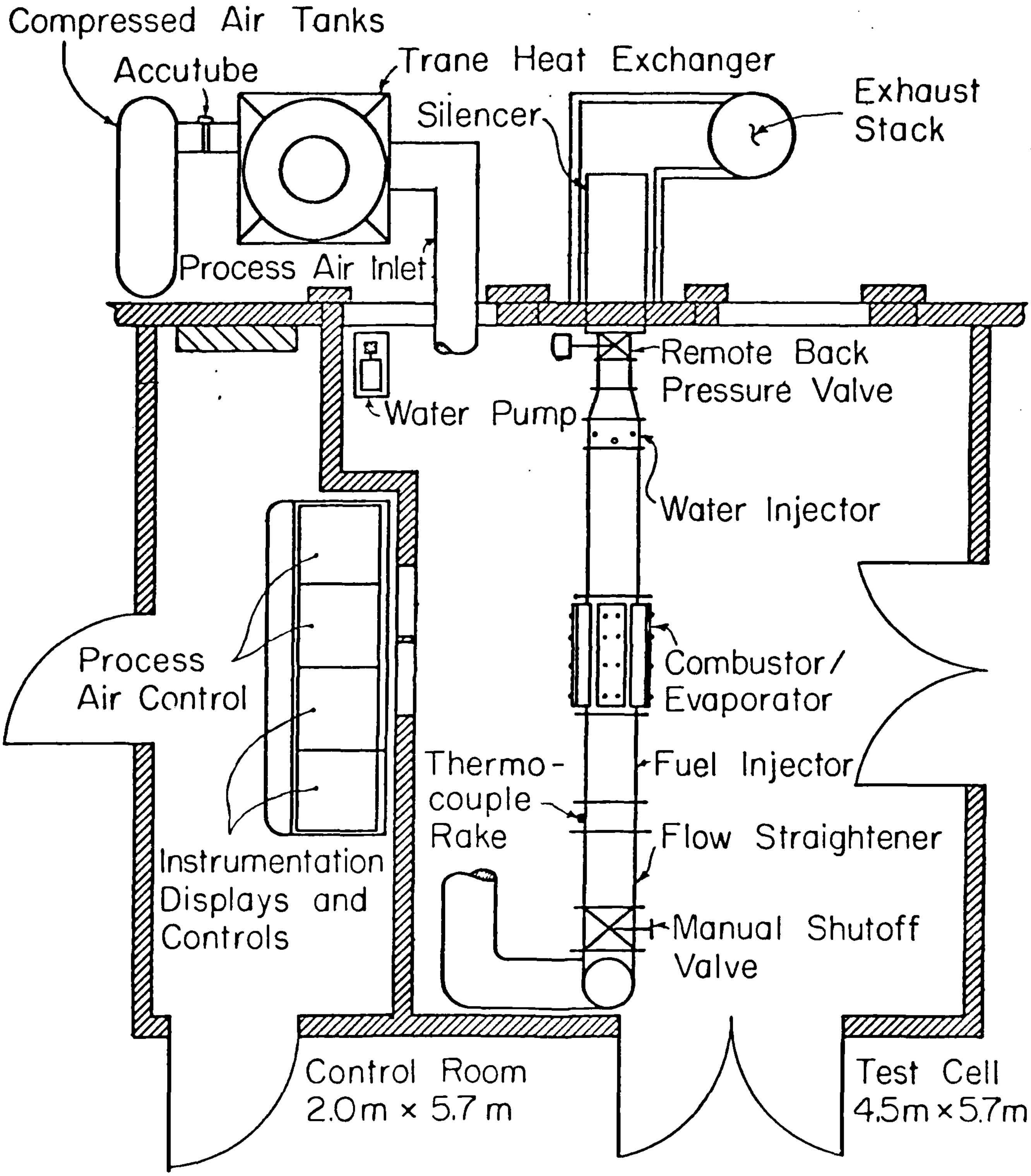

Figure 4. Experimental facility

water cooling reservoir. A monodisperse spray of fuel is introduced in the first test section. After evaporation rate measurements have been made, the fuel spray is ignited with a methane torch to burn the fuel before it is exhausted. For flame speed measurements the fuel is ignited with an electrically heated wire stretched across the test section at a location where drop sizes and vapor phase equivalence ratios have been measured from the evaporation rate experiments. The angle of the flame spread across the test section is then observed in order to determine the flame speed.

Further downstream cooling water is injected into the duct to lower the exhaust gas temperature to 540° C to prevent damage to the back pressure valve and silencer. The exhaust products then flow through the silencer into a 5.5 m vertical exhaust stack to the atmosphere.

B. Air Flow Heating and Control

The Trane Thermal heat exchanger is an oil fired unit outfitted with a Thermal high velocity burner. The process air first flows through a coiled tube pass, and secondly through a straight tube or inner pass. Major renovations were required to upgrade the heat exchanger for our experiments. These included the design and construction of a new control station that is incorporated into the combustion rig control panel. Of particular importance was the calibration of the air/fuel ratio of the burner, in order to achieve the optimum equivalence ratio over its entire operating range. Also, an Accutube brand flow measuring system was installed in the process air inlet duct. This placement allows mass flow measurements to be made at near ambient conditions rather than at the elevated and

variable temperatures downstream of the heat exchanger. To minimize heat loss, new insulation was installed on all of the process air ducts leading into the test cell.

C. Test Section Details

As shown in Fig. 5, the main test section consists of two flow straighteners, a fuel injector, and an evaporator/combustor. A second evaporator/combustor section is planned, and is shown in dashed lines in Fig. 5. This section will feature improvements derived from operational experience with the first one. The major criteria which dictated the design were: (1) assure a uniform air flow profile upstream of the fuel injection; (2) provide a sufficiently large viewing area for optical measurements; (3) allow for access along the axis of the duct for sampling probes and instrumentation taps; (4) assure minimum flow disturbances along the observation windows and access plate; (5) withstand the high air temperatures and pressures. The last requirement stipulated the use of heavy wall stainless steel pipe and special quartz windows. A photograph of the facility is given in Fig. 6.

1. Flow Straighteners

The entire test chamber is a 14.6 cm inner diameter circular duct. The upstream flow straightener is 0.76 m long, consisting of an array of 0.64 cm diameter thin wall brass tubes 0.38 m long. The tubes are placed in the downstream half of the pipe to allow the air, after flowing through the inlet elbows and gate valve, to expand before entering the straightener. The tube size in the flow straightener was selected such that fully developed flow exists within

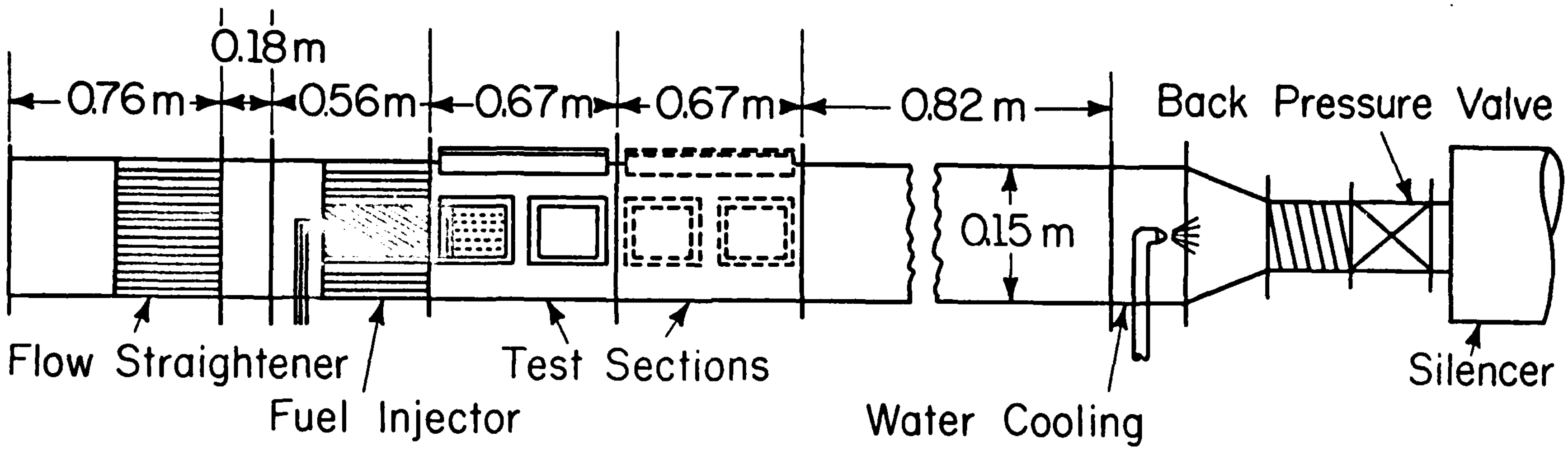

Figure 5. Test facility schematic

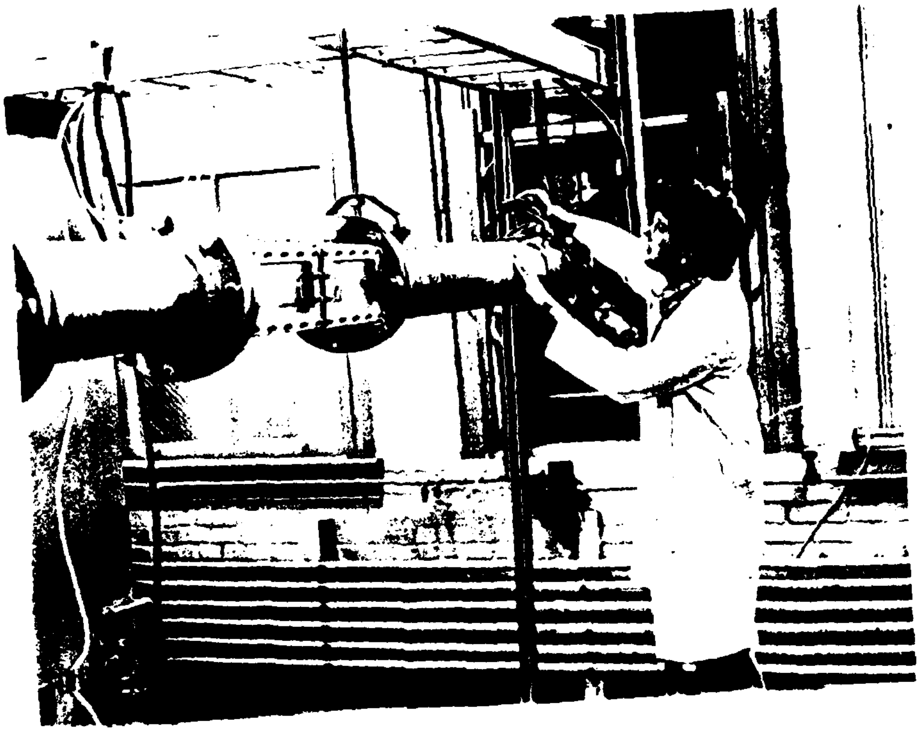

Figure 6. Test cell photograph

the Ø.38 m length over the full range of operating conditions.

The next component is Ø.18 m long and was designed primarily to facilitate removal of the fuel injector section. A thermocouple rake is inserted into this section to provide the inlet temperature profile.

The fuel injector section contains the fuel injector body, the cooling reservoir/holder, a second flow straightener, and a manifold for fuel, water, and electrical access, as shown in Fig. 7. The cooling reservoir is required due to the acoustic exciter used in the injector body, which will fail if subjected to high temperatures. It is also utilized to maintain the fuel at near ambient temperatures until the point of injection. To best achieve this, the fuel line is concentric with the inlet water line. The cooling reservoir/holder, as illustrated by Fig. 8, was fabricated from 5 cm inner diameter stainless steel tubing with various attachments as shown. The temperature at the acoustic exciter is monitored with a thermocouple in order to ensure that proper cooling is maintained. The injector assembly is held in position by the second flow straightener shown in Fig. 9. It is designed such that the entire fuel injector assembly may be removed with the duct still in place by sliding it out the upstream end after the thermocouple rake section is removed. The second flow straightener is of the same diameter brass tubes as the first, but is 3Ø.5 cm long. Further details on the injector can be found in Section-C.

2. Test Section

The evaporator/combustor section is the main component of the test rig and a photograph of this section is shown in Fig. 1Ø.

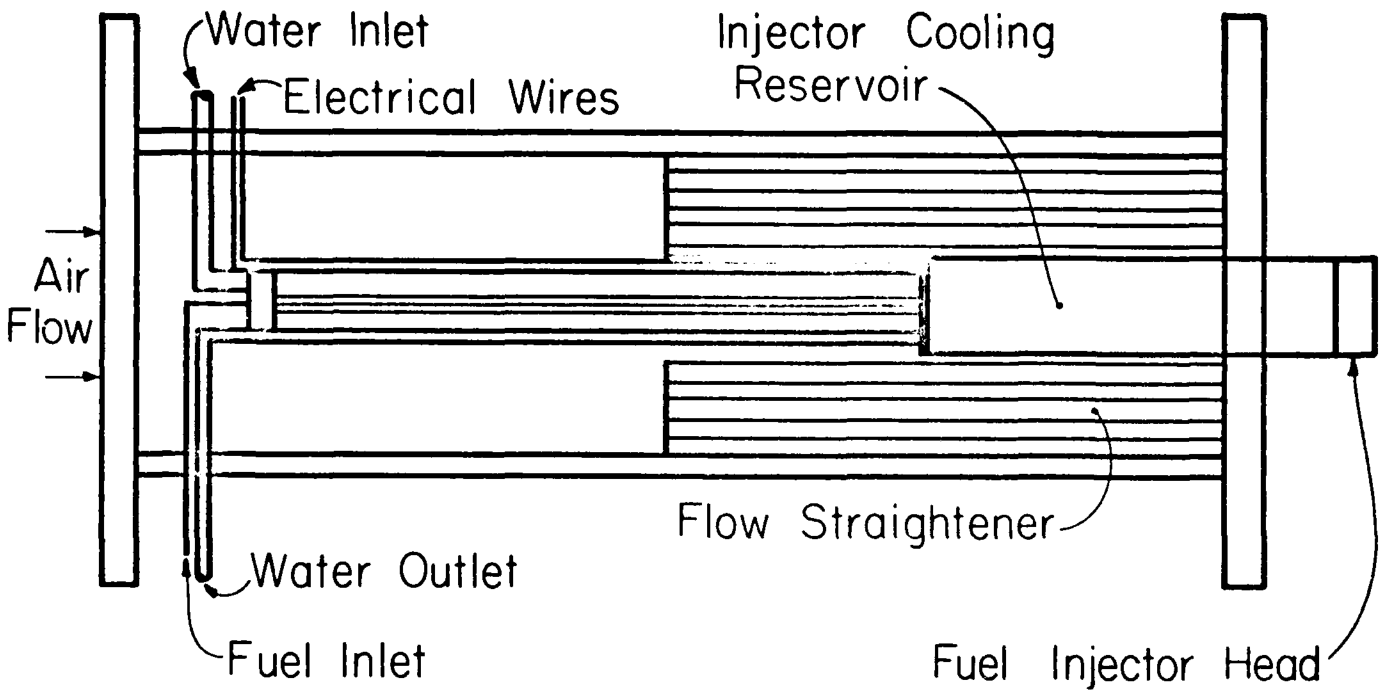

Figure 7. Schematic of fuel injector section

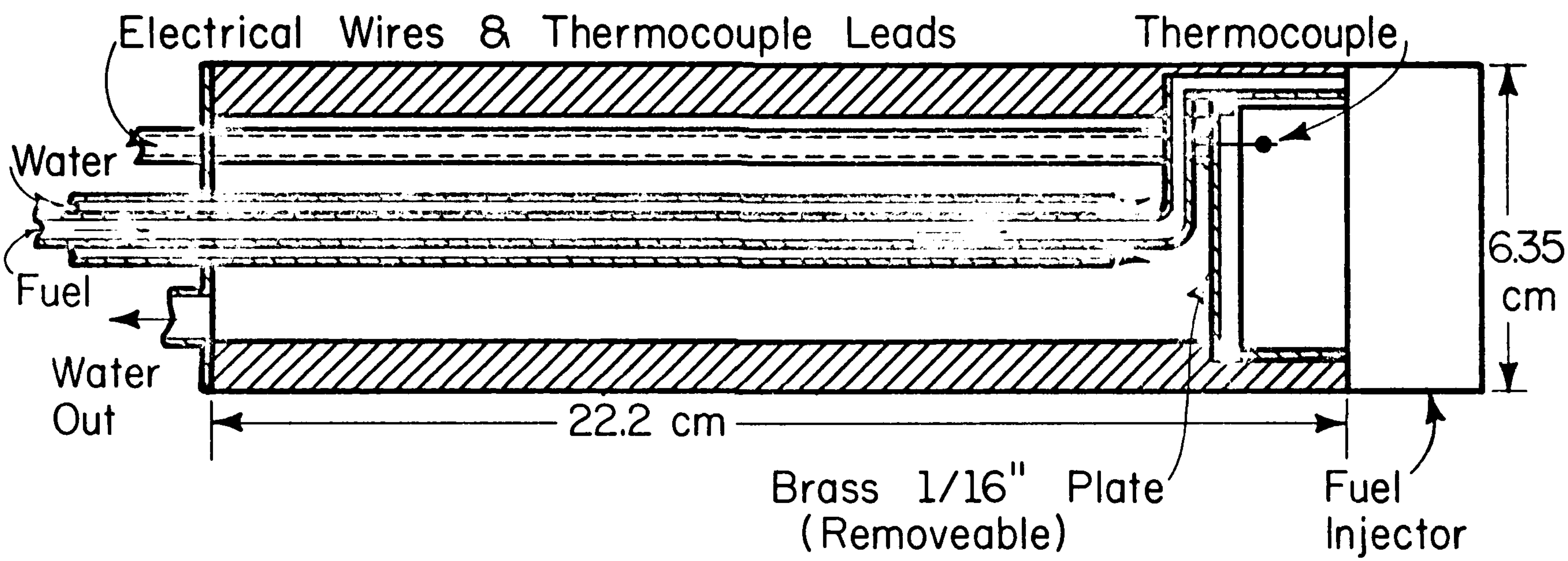

Figure 8. Cooling reservoir/fuel injector holder

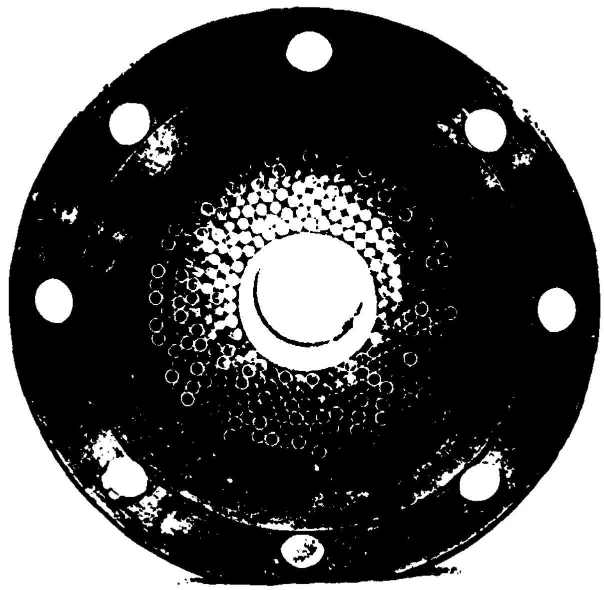

Figure 9. Flowstraightener and fuel injection holder

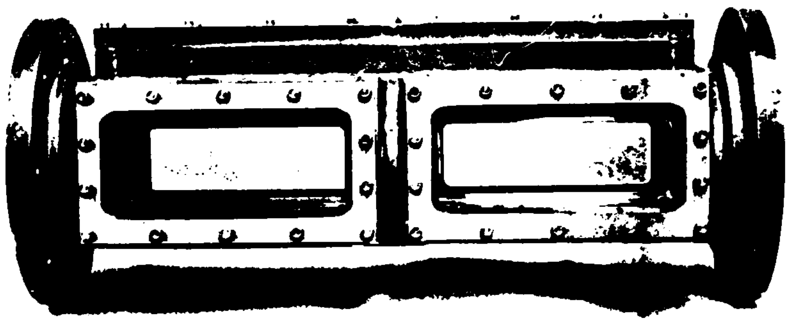

Figure 10. Photograph of evaporator/combustor test section

Presently, one section has been built and is undergoing initial testing. The four 2.5 cm thick quartz windows are aligned with the observation windows in the control room so that the operator may observe the experiment. The face of the fuel injector is placed in line with the edge of the first window so that observations of the drops can be made while they form. The fixtures that hold the windows were designed to provide maximum viewing area while disturbing the flow as little as possible. The quartz is easily removed for cleaning and for access to the inside of the section. An instrumentation access plate located on top of the evaporator/combustor provides for multiple insertion points along the axis of the test section for the phase discriminating probe, static pressure taps, thermocouples, and igniter. The inner wall of this plate is machined with a curvature which conforms to the inner diameter of the pipe.

3. Igniters and Sampling Systems

Two types of igniters were constructed. One is a methane igniter which is inserted to burn the fuel when only evaporation rate measurements are taken. The other igniter is an electrically heated wire oriented transverse to the direction of flow. This wire serves as the igniter for the flame speed measurements.

Details of the phase discriminating sampling probe are illustrated in Fig. 11. Isokinetic sampling is achieved by matching the pressures obtained from internal and external static pressure taps. The gas phase equivalence ratio is determined by withdrawing vapor at a right angle from the main sampling tube. The total fuel to air ratio is obtained through the main tube. As a second check on the gas phase equivalence ratio, the probe will be operated in the

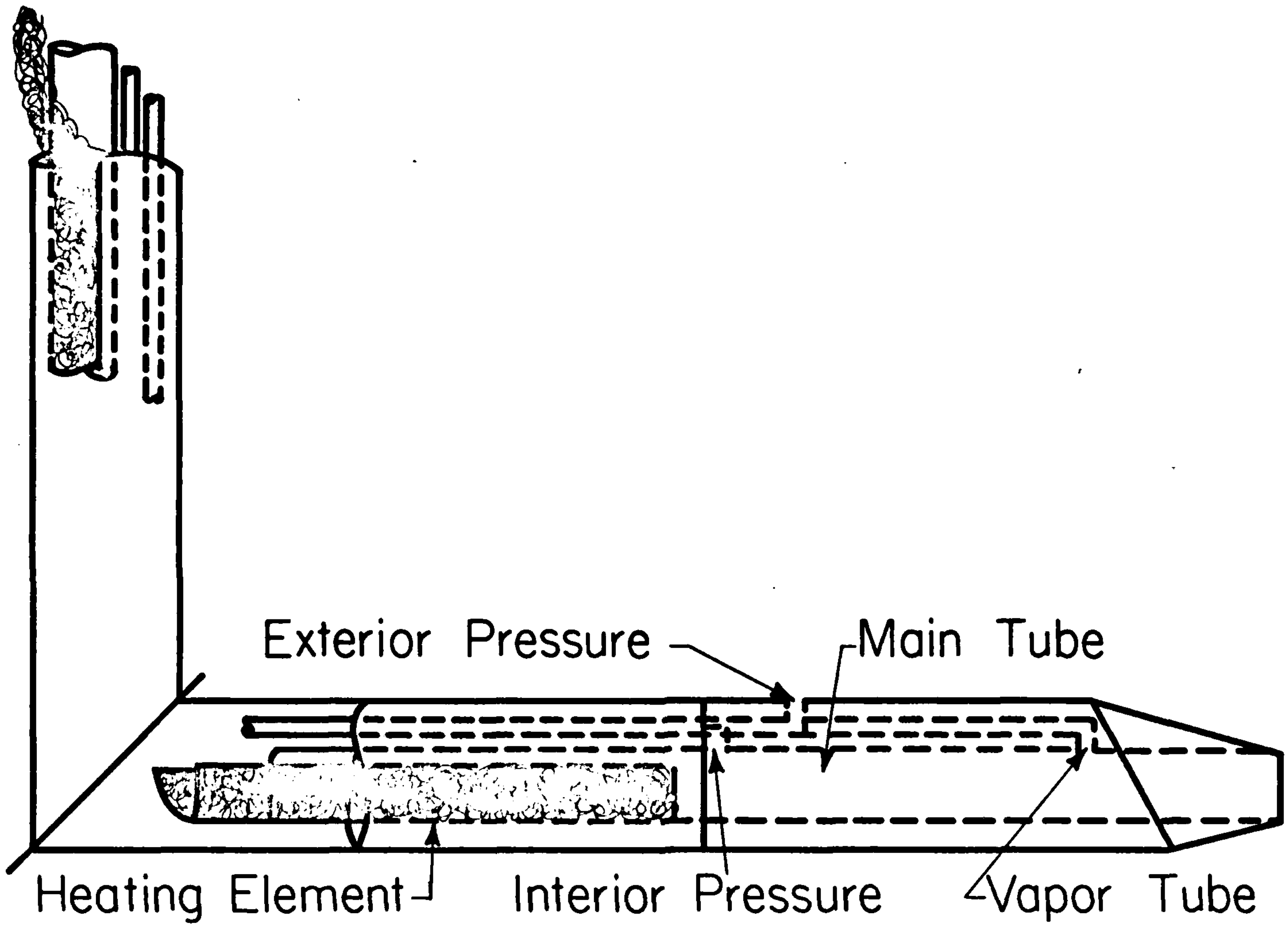

Figure 11. Phase descriminating probe

standard "spillover" mode to separate the total and gas phase equivalence ratios. As shown the probe is electrically heated to prevent "puddling" of the fuel.

The gas sampling scheme is shown schematically in Fig. 12. After being withdrawn from the test section oxygen is added to obtain a lean mixture prior to combustion in an electrically heated oven. The products of combustion are cooled and the water is removed prior to their introduction into the gas analyzers. The CO and CO_2 are measured with Beckman NDIR analyzers and the O_2 with a Beckman polaragraphic analyzer. Carbon monoxide is monitored to ensure the combustion is complete and with the CO_2 and O_2 concentrations plus the carbon to hydrogen ratio of the fuel, the equivalence ratios in the test section are obtained.

4. Exhaust System

Further downstream from the combustion zone, water is injected to cool the exhaust. A water injection section is located just before the back pressure valve. This section consists of three radially oriented flat spray nozzles and one axially oriented solid cone nozzle. The flow rates to these injection points can be independently regulated by a gate valve distribution system in the control room. The cooling water is provided by a Sherwood gear pump. To ascertain that proper cooling is being achieved, the exhaust temperature will be monitored and kept below 540° C to prevent damage to the back pressure valve and silencer.

The silencer is a Riley-Beaird model custom made to our specifications. It is predicted to reduce the valve noise from an estimated 120 dbA to 90 dbA in the test cell.

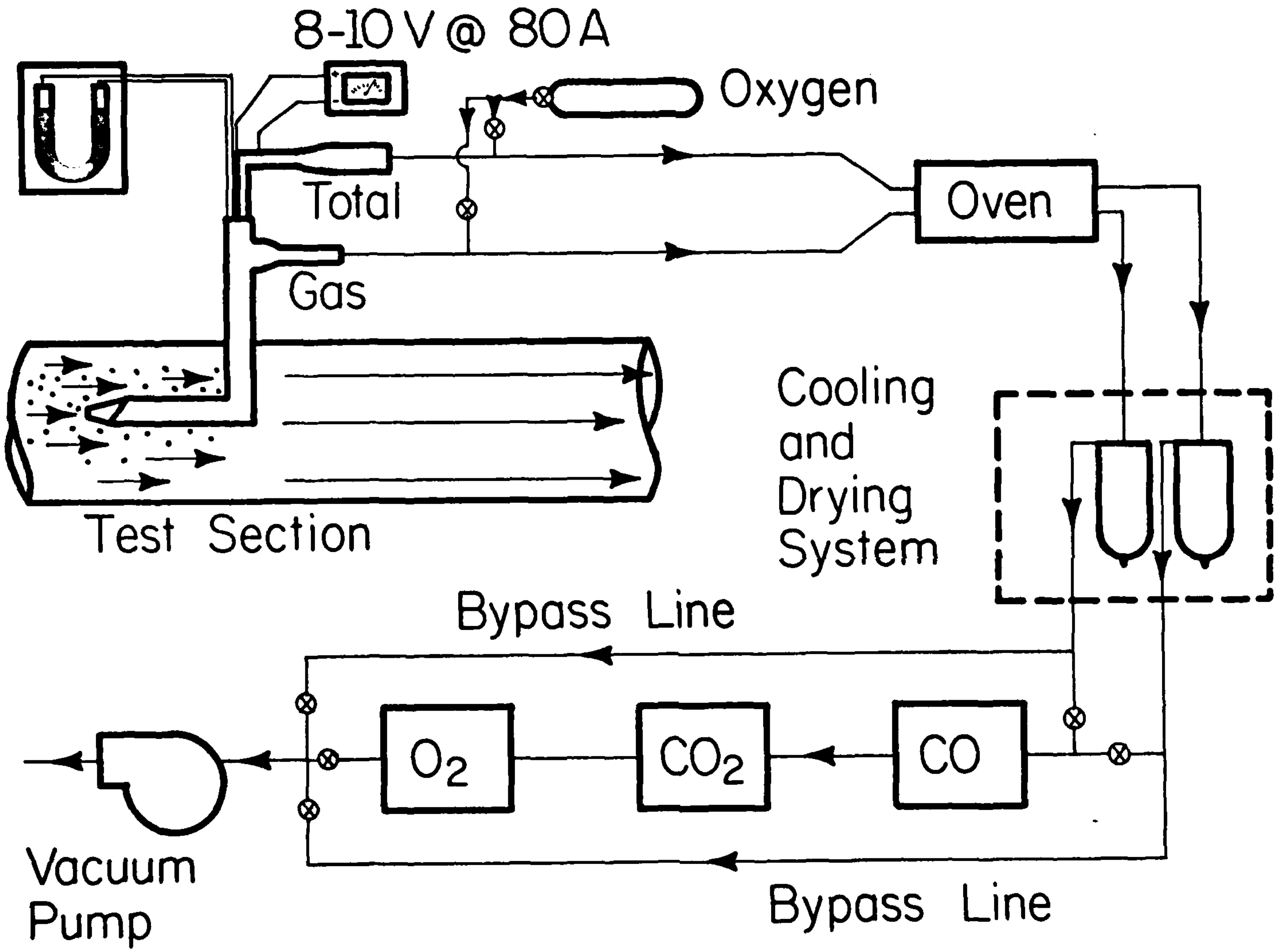

Figure 12. Gas sampling schematic

D. Special Fuel Injection System

To enable the mass production of monodisperse fuel sprays of controlled size and to be able to change the drop velocities and the drop-to-drop distances, a special fuel injection system has been designed, constructed, and tested. The basic physical process employed is that of Rayleigh[17], which consists of launching a well-tuned acoustic wave along the symmetry axis of a smooth jet so that the jet can break up into uniform-size droplets in a stable, controlled manner. Producing smooth fuel jets of desired size and implementing an appropriate acoustic-wave-launching mechanism are, therefore, integral parts of the fuel injector development work.

1. Description of Apparatus

A prototype fuel injection system capable of producing a multi-stream of monodisperse fuel droplets is schematically shown in Fig. 13. As indicated in the diagram, a controlled amount of fuel flows from the pressurized fuel dispensing vessel through a filter and a flowmeter into the fuel sprayer unit. The sprayer unit, which is the heart of the entire fuel injection system, is designed such that it can produce a controlled number of smooth fuel jets of predetermined size when the acoustic wave launcher, which is part of the unit, is not activated. The wave launcher is effected by an oscillator tuned to an appropriate set of amplitudes and frequencies, and is responsible for the break-up of the fuel jets into a multi-stream of monodisperse sprays. By controlling the oscillator parameters and fuel flow rate (which are all external parameters), the size, spacing and velocity of the fuel drops can be varied within the operational limit of the wave launcher and the oscillator. For the

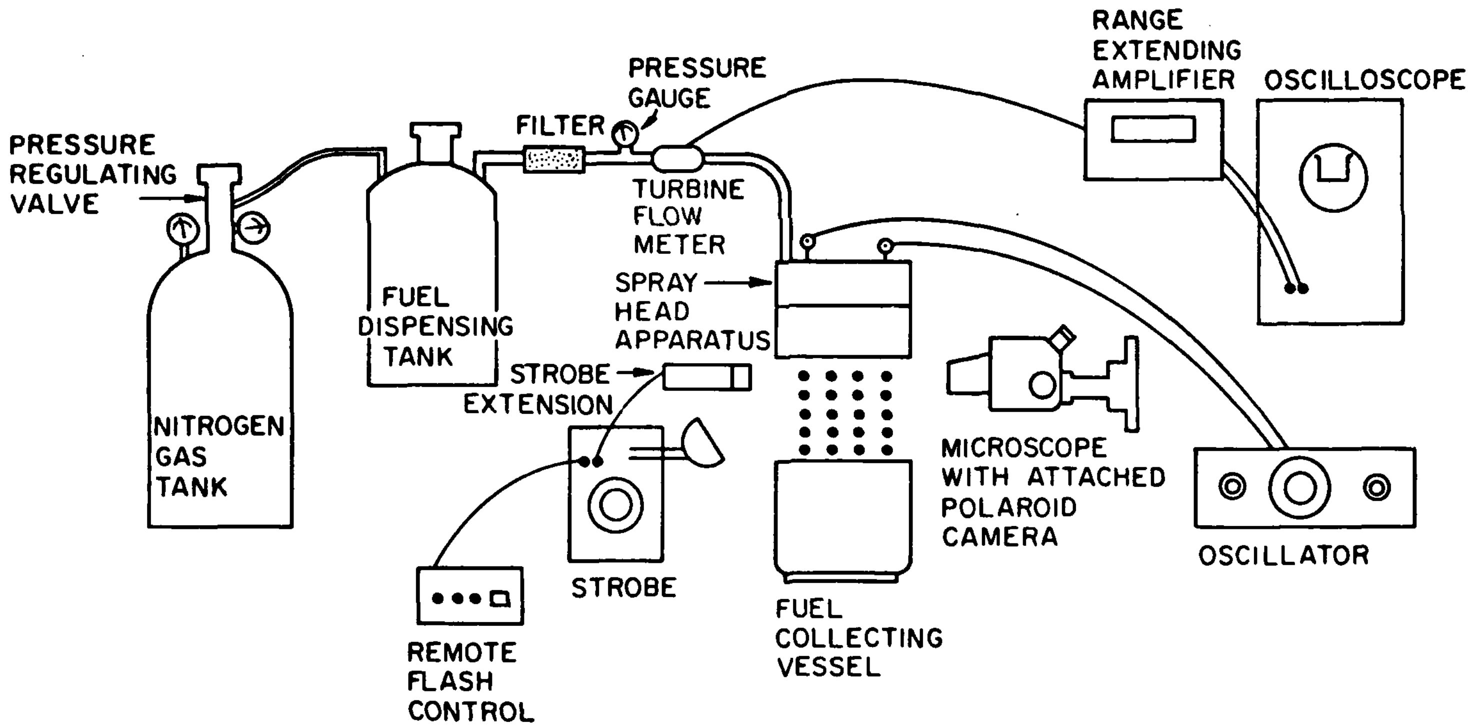

Figure 13. Schematic of a prototype fuel injection system capable of producing a multi-stream of monodisperse fuel drops

most stable fuel spray, however, substantial drop size variation is not usually possible. Consequently, it is often necessary to change the sprayer head to one having smaller/larger holes when significantly smaller/larger fuel drops are desired. In practice, therefore, the spacing and velocity of the fuel drops are the only parameters which can easily be subjected to changes.

2. Discussion of Experimental Results

To develop a reliable fuel injection system which can be subjected to the high pressures and temperatures of the combustor, a variety of fuel injector designs were conceived. The performance of each design was then evaluated using a skeletal prototype system. Based on this feasibility assessment, a high-performance fuel injector design was chosen, further elaborated for reliability, and finally integrated into the design of the fuel injection system compatible with the high-temperature, high-pressure environment of the combustor.

Figure 14 shows a picture of a linear array of monodisperse droplet streams produced by the currently operated fuel injection system. The droplets are clearly seen to be uniform, with their trajectories regular and stable. (The fact that some streams are closer to each other than others is <u>not</u> a reflection of the poor system performance, but rather an indication that the injector head has holes either not in alignment with one another or partially clogged with impurities. Since these defects can be corrected with proper care in manufacture and maintenance, they are not considered matters of great concern.) The working fluid was distilled water and the injector configuration was such that the drop streams were made to travel vertically downward. The drops are ~70 μm in diameter and

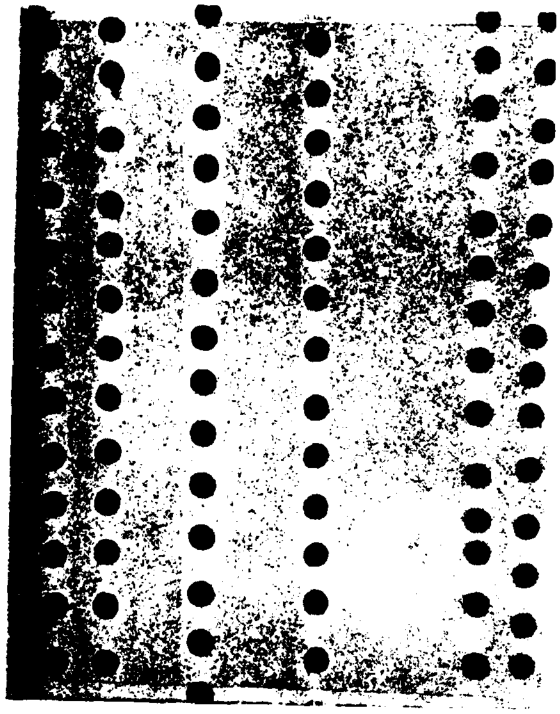

Figure 14. Linear array of monodisperse droplets (drop diameter $\simeq$ 70 μm)

their production rate is 27 kHz for each stream. The drop velocity at the exit end of the fuel injector is estimated to be ~10 m/s.

Monodisperse water sprays produced by an injector head having a two-dimensional array of collimated hole structures are shown in Figure 15. The drops are again ~ 70 μm in diameter, and only the ones traveling along the focal plane of the viewing microscope objective have clear images in the picture. The upstream drops do not appear perfectly spherical due to the fact that they are still going through the mechanical vibrations (which are, in the first place, responsible for the breakup of the smooth jets into uniform drops). As expected, the downstream drops are seen to be more spherical. The velocity and production rate of the drops are, respectively, ~10 m/s and 36.4 kHz. The total flowrate is approximately 0.7 ℓ/min for this particular run, which of course can be varied during the experiment by choosing a different set of operational parameters.

To summarize, a prototype fuel injection system capable of producing monodisperse fuel sprays has been described. Using the system, monodisperse water sprays of controlled size, flowrate, velocity and interdrop distance were produced. For simplicity of the fluid-handling system and sanitary reasons, distilled water has thus far been used as the working fluid. However, it must be emphasized that there are no fundamental differences between the properties of water and those of fuels which can drastically affect the operational characteristics of the current fuel injection system and, therefore, that no major obstacles are expected in operating the system with actual engine fuels. To prove this point, although very preliminary, a picture of a 70 μm diameter monodisperse, single-stream jet A fuel spray is shown in Figure 16. It is evident that the present fuel

Figure 15. Two dimensional array of monodisperse droplets (drop diameter $\simeq$ 70 μm)

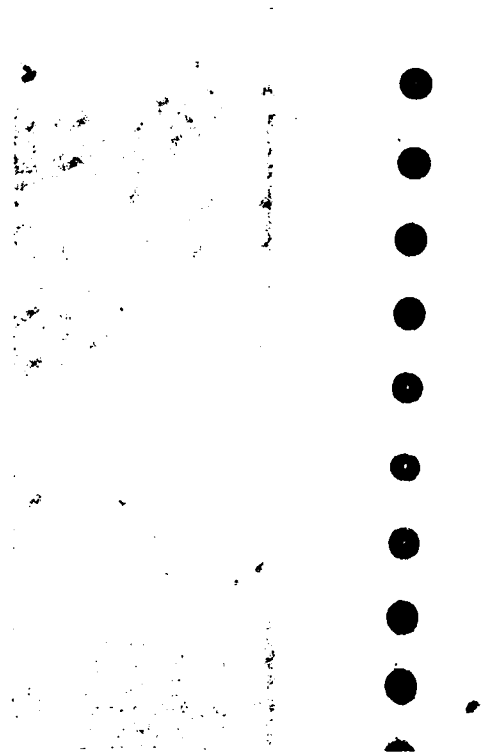

Figure 16. A single-stream, monodisperse spray of jet fuel

injection system works equally well with the actual fuel.

We are currently in the process of installing the auxiliary components required for the safe handling of fuels at high pressures and temperatures. Actual fuel spray data, which should be consistent with the water spray results included in this report, are therefore expected in the near future.

III. CONCLUSIONS AND FUTURE EFFORTS

A. Experimental Program

In this report we have described the engineering design for the construction of a test facility that will be used to study alternative fuel spray evaporation and combustion. Considerable man-months were required to design, manufacture and install the combustion-flow system into our laboratory. One of the key features of this experimental program is the availability of an air supply facility which can deliver high temperatures (up to 900 K) and pressures (up to 800 kPa) at continuous flowrates approaching one kg/sec. Another important aspect of the facility is the fuel injection system which produces monodisperse sprays, where drop spacing, liquid drop velocity and spray size can be controlled.

With the construction of the facility nearly complete we are currently in the process of conducting shakedown tests to fully characterize all operating parameters. These preliminary tests will include characterizing air inlet velocity profiles and average turbulence levels, as well as gas sampling probe calibrations, and the testing of the optical diagnostic measurement systems. For example, a laser diffraction particle sizing system to be used in this program is being used and tested in a pulsed spray study. This system will require some modifications before it can be applied to this alternative fuels, evaporation and combustion program. In addition a laser doppler velocimeter (LDV), to be used for velocity and turbulence level measurements, has been purchased and is scheduled to arrive in late March 1984. Design of the particle seeding system and flow measurements will also be a high priority during the initial part

to us by NASA Lewis Research Center. This code was written to compute the gas phase turbulent flow field and then allow one to superimpose a spray onto the gaseous flowfield. It is then be possible to compute droplet trajectories and evaporation, assuming that the gaseous flowfield is unaltered. The spray is modeled by dividing the spray into a set of classes (specific drop sizes, temperatures and velocities) and these classes are tracked through the previously computed gas phase flowfield.

The second model being used is the Los Alamos CONCHAS-SPRAY code.[20] In this code the gas phase and spray are completely interacting with gas phase computations being Eulerian in nature and a Lagrangian approach is applied to the particles. The spray is represented by a discrete-particle technique with the characteristics of a particle statistically assigned using a Monte Carlo sampling scheme.

The results obtained from the UTRC and Los Alamos codes will be used to aid the development of our own version of a two-phase flow code and to facilitate the interpretation of the experimental portion of the research program. Model and experimental results will be compared in an effort to better understand the spray evaporation/combustion process and to improve current spray modeling techniques.

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